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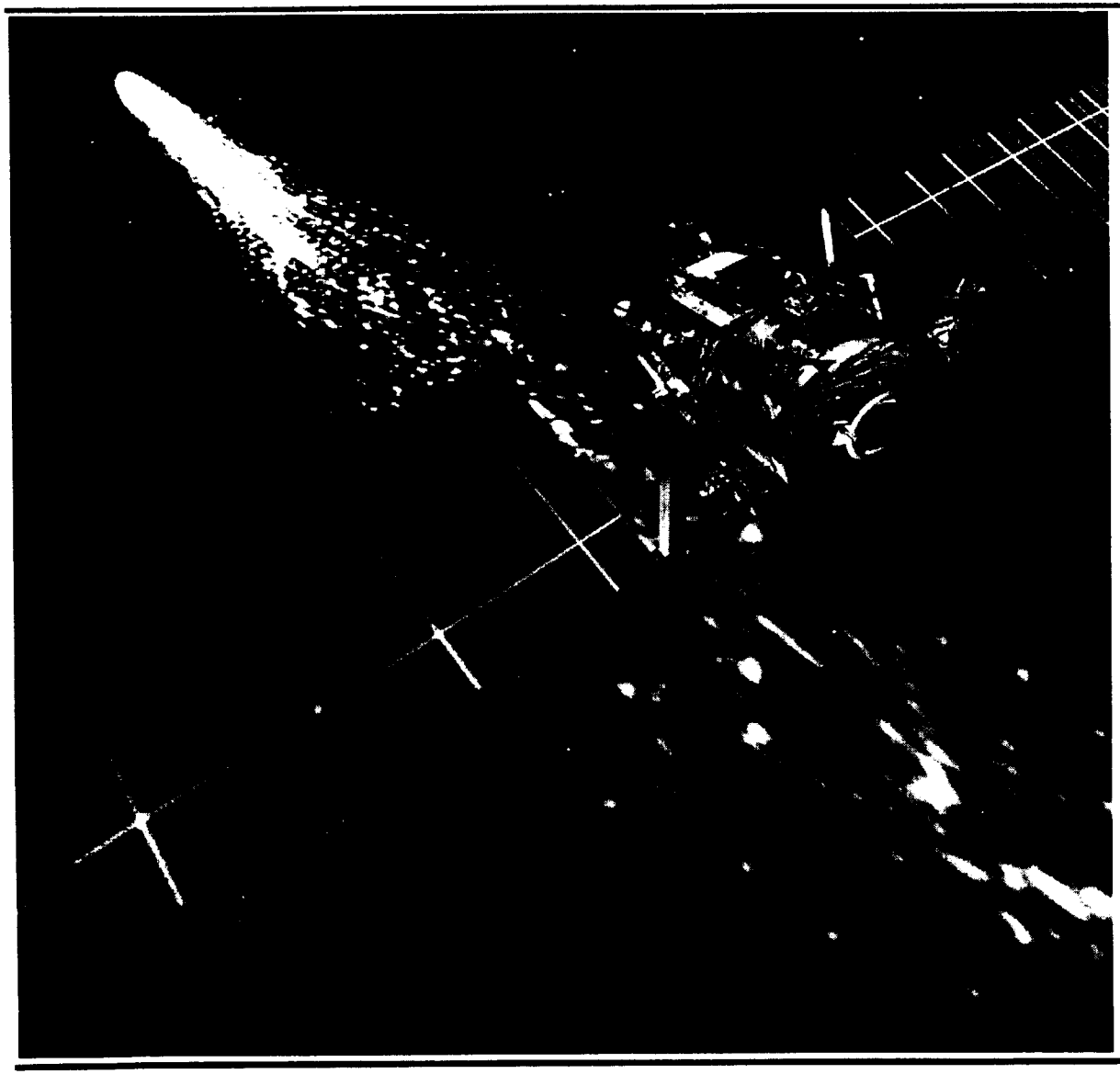

Deep Space One

High-Voltage Bus Management

Ken Rachocki
Spectrum Astro, Inc.

Donald Nieraeth
Jet Propulsion Laboratory
California Institute of Technology

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OVERVIEW

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Ken Rachocki	High Voltage Bus Requirements
	Design & Fabrication of High Voltage Power Converter
Don Nieraeth	Testing & Stability
	Operations
	Flight Data & Analysis
	Conclusions

Acknowledgments:

Jet Propulsion Laboratory California Institute of Technology	Deep Space 1 Mission
Spectrum Astro	Industry Partner for Deep Space 1
Al Ahrens	Preliminary Design of HPCU
Curt Copeland	Final HPCU Design and Build

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HIGH VOLTAGE BUS REQUIREMENTS

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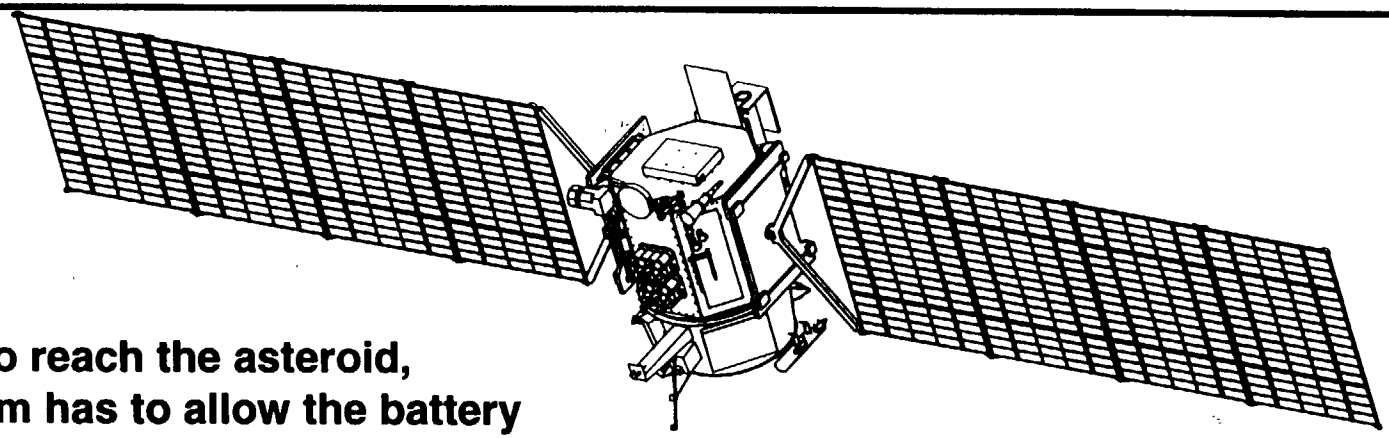

For the spacecraft to reach the asteroid, the power subsystem has to allow the battery to support S/C loads occasionally during IPS thrusting.

Other HPCU Design Requirements

- **HV Switching for PPU & PPU Heaters (2500W, 100W & 70W, respectively)**
- **33+1/-11V @ 18.2 A Maximum for Spacecraft Power**
- **Provide Battery Charge Control**
- **Load Each of 8 Solar Cell Modules to Measure I-V Profiles of Array Segments**
- **Provide Current and Voltage Telemetry from Solar Array and Batteries**

Significance of the Requirements

- **As the available power from the solar array power decreases as the square of the distance from the sun, the need to operate near the peak power point is paramount in accomplishing the mission goals.**

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THE HIGH VOLTAGE BUS INTERFACES

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- Solar Array
  - Output voltage range is from 80 V to 120 Vdc.
  - Estimated output power is 2500 W at 1 a.u. from Sun.
- High Voltage Power Converter Unit (HPCU) - Original Requirements
  - Converts high voltage to low voltage (~32 Vdc) while providing up to 18 A to the engineering loads and science instruments.
  - Includes a charge control unit to charge the battery based on one of 16 V-T (voltage-temperature) curves to account for cell aging, cell short, and trickle charging.
- Power Processing Unit (PPU) - part of the Ion Propulsion Subsystem (IPS)
  - Converts high voltage to seven voltages to drive an ion thruster.
  - Designed to provide over 2300 W of output power.
- PPU Heaters
  - Keep the PPU from getting too cold during low power and "off' operation.

DS1 POWER SYSTEM ARCHITECTURE

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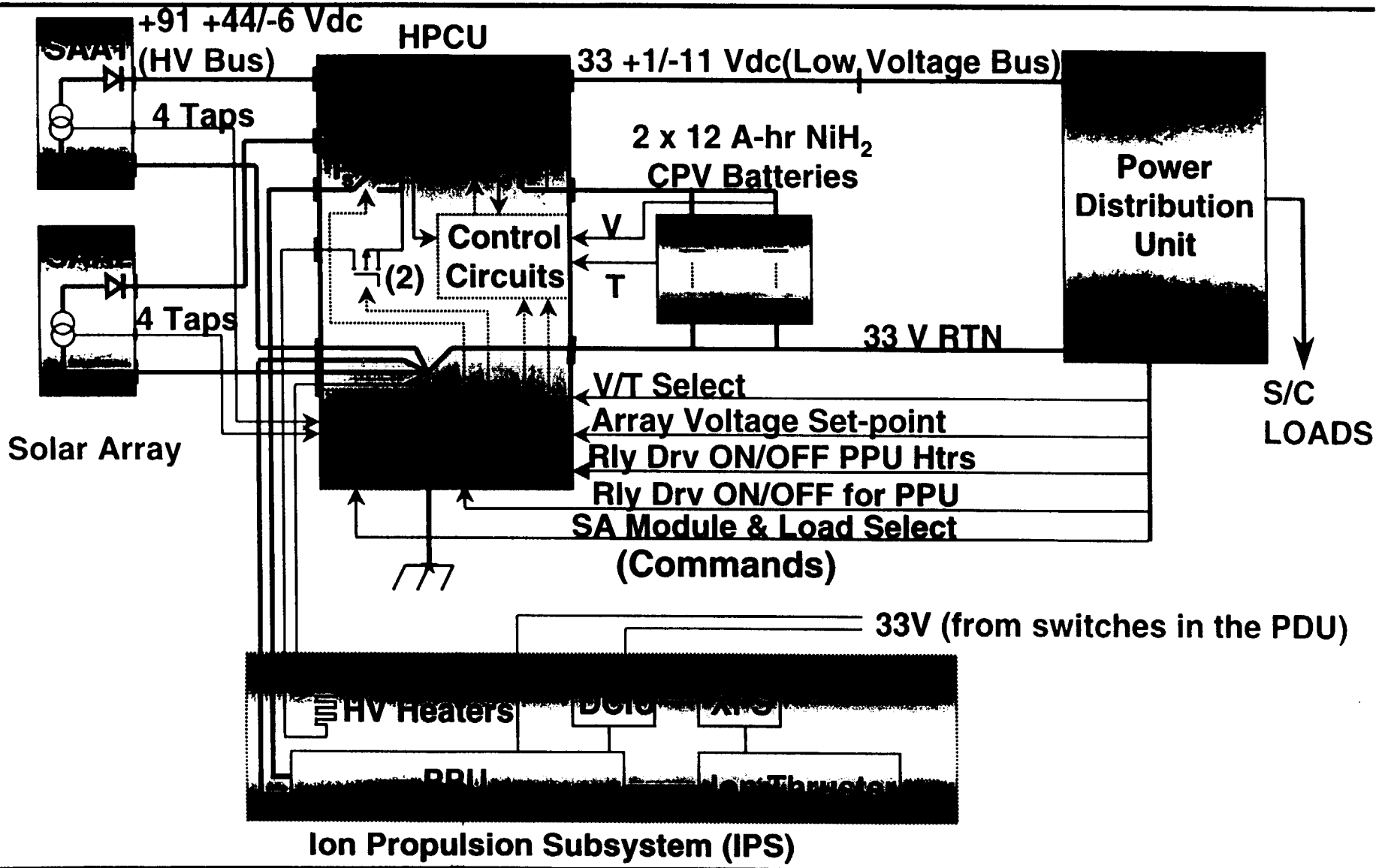

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THE HPCU DESIGN CHANGE

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With the original HPCU design, the array voltage would collapse if the spacecraft loads (including PPU/thruster) demanded more power than the solar array could supply.

Initially, the use of a Peak Power Tracker (PPT) was considered.

- **Incorporating a PPT in the HPCU has very limited advantage since it is a small load (~450 W) on the SA bus.**
- **The goal was to maximize power to the PPU not the spacecraft loads.**
- **The PPU being a 2500 W load is a better choice for implementing a PPT.**

Since the PPU design was frozen, the decision of a PPP approach was abandoned.

The focus shifted to modifying the HPCU design.

- **Additional control loop was added in the HPCU that allows regulation to an array voltage set-point selected by an up-link command.**
  - **The flight operations team or an on-board sequence can command any one of 64 array voltage set-points in the HPCU.**
  - **The voltage range is 78 to 132.4 Vdc in 64 x 0.85 volt steps.**
- **Based on the projected estimate of the PPT voltage, the array voltage regulation set-point is selected near the PPP.**

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HIGH VOLTAGE BUS STABILITY TESTING

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Using a solar array simulator as a power source, compatibility tests were performed with a HPCU breadboard and a PPU breadboard.

The test results showed that although the PPU with a thruster load generated some noise on the high voltage bus, the HPCU performed in a stable manner.

Collapsing the array voltage did not affect the operation of either the HPCU or the PPU.

As expected, the magnitude of the noise on the high voltage is dependent on the grounding configuration.

- A single-point ground approach is used on the spacecraft for power return lines; the star ground is near the power source.

On-board flight tests indicate that the HPCU can operate at a set-point voltage on either side of the PPP (without collapsing the array voltage).

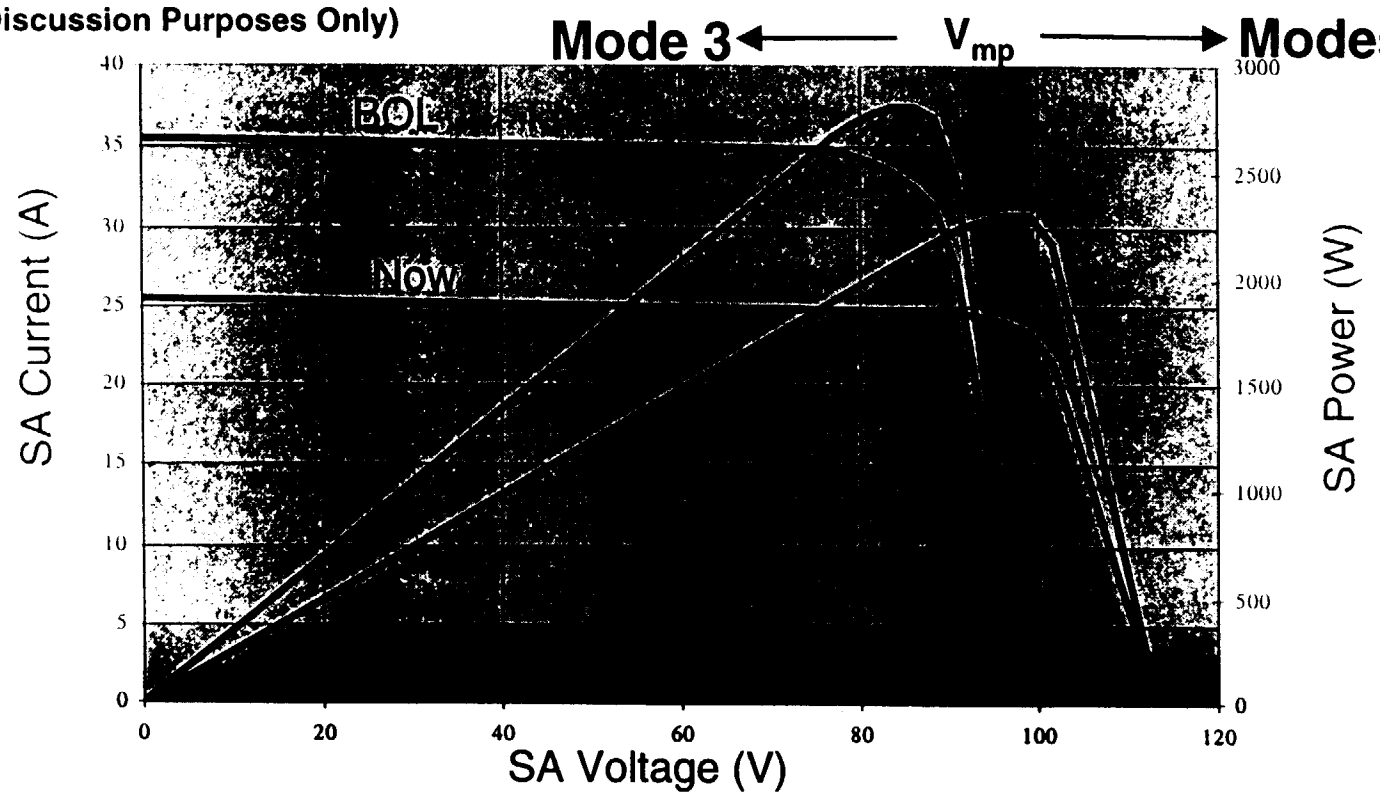
SPACECRAFT ON-ORBIT OPERATIONS

To provide maximum power to the IPS during the thrusting phase, the spacecraft has to operate near the PPP of the array.

- **A predetermined minimum required loads are turned on during this phase.**
- **Based on a projected PPP voltage, an up-link command is sent to the HPCU to have the array operating voltage set-point selected slightly to the right of the PPP.**
  - **The set-point selection is updated every week during spacecraft tracking.**
- **The IPS is commanded to a throttle level that corresponds to the maximum projected power from the array minus the expected spacecraft power consumption.**
- **If the battery discharges too deep (projected to reach 65% SOC in about 30 minutes), then a software algorithm on-board sends a command to IPS to throttle back one step autonomously.**

FLIGHT DATA & ANALYSIS

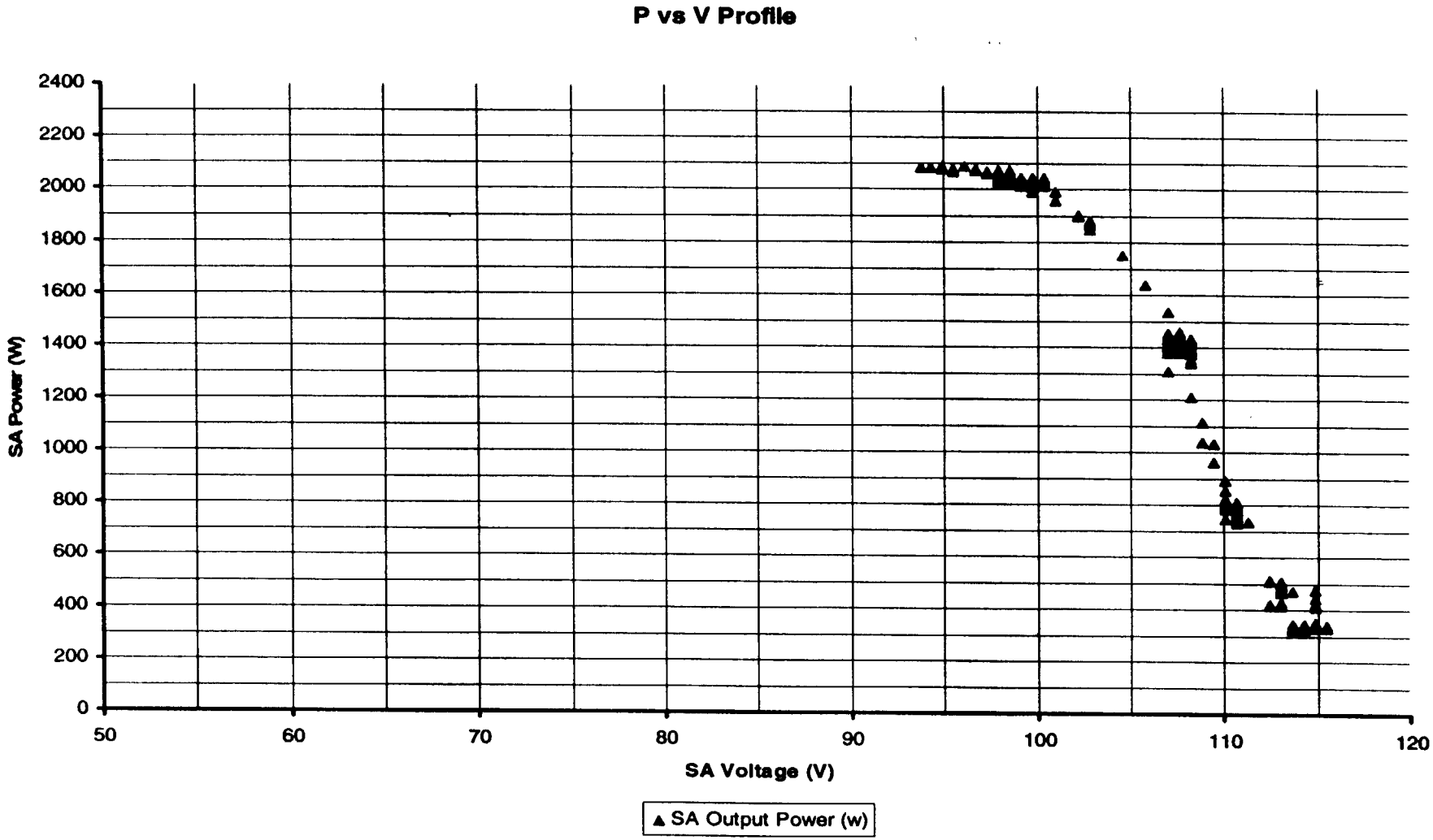
(For Discussion Purposes Only)



1. Upon sun acquisition, HPCU operates in battery current limit mode
2. During nominal cruise, HPCU operates in V-T battery charge limit mode.
3. While thrusting, HPCU operates in solar array voltage control mode; the voltage set-point is near the PPP.

FLIGHT DATA & ANALYSIS (cont.)

Results from a PPP search test performed in flight



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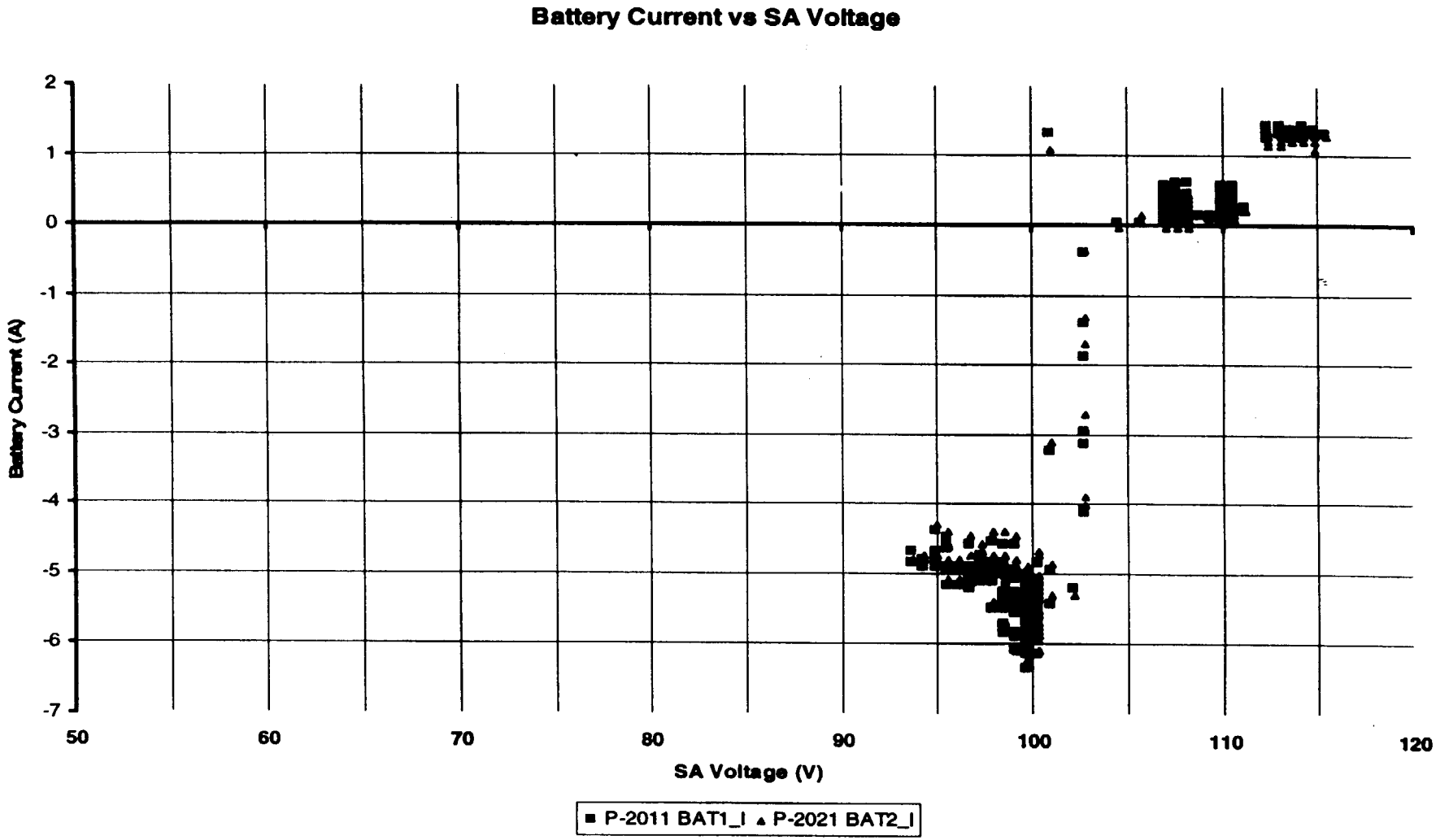

SUMMARY

The design of the High Voltage Power Converter Unit on DS1 allows both the spacecraft avionics and ion propulsion to operate in a stable manner near the PPP of the solar array.

- **This approach relies on a fairly well-defined solar array model to determine the projected PPP.**
- **The solar array voltage set-points have to be updated every week to maintain operation near PPP.**
- **Stable operation even to the LEFT of the Peak Power Point is achievable so long as you do not change the operating power level of the ion engine.**

The next step for this technology is to investigate the use of onboard autonomy to determine the optimum SA voltage regulation set-point (i.e. near the PPP); this is for future missions that have one or more ion propulsion subsystems.